K-Ar Ages of Volcanic Rocks in the Samburu Hills Area, Northern Kenya

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K-AR AGES OF VOLCANIC ROCKS IN THE SAMBURU HILLS AREA, NORTHERN KENYA

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ABSTRACT 44 volcanic rocks collected systematically from the Samburu Hills area, west of Baragoi, Northern Kenya were dated with the K-Ar age determination method to examine the chronology of fossil hominoids discovered in the Japan-Kenya Expedition, 1982. The K-Ar data suggest that Samburu hominoids at the site SH-22 are from 7.1±0.5 to 10.7±0.6 Ma in age and the Kenyapithecus at the Site BG-X from 12.6±0.6 to 14.9±0.6 Ma in age.

INTRODUCTION

In the East African Rift system, the eruptions of huge amount of alkaline rocks took place during the formation of the continental rift. The age of first volcanic activity and the first phase for the formation of rift system get gradually younger from the northern to southern area (Pilger & Rosler, 1975 ; Baker *et al.,* 1971). However, the geochronological study of volcanic rocks in each area is so rough, especially in Gregory Rift system, northern Kenya, where fossil hominoids have been occasionally discovered by some expedition parties (e.g., Ishida, H., 1984). This has made it difficult to discuss in detail palaeoanthropology as well as volcanic geology in and around the rift system. Recently, in some areas where fossil hominoids have been discovered, the chronological investigation of or around the sediments including the fossils seems to be done with K-Ar, fission track and paleomagnetic methods (e.g., Hill *et al.,* 1985 and Matsuda *et al.,* 1984). This paper treats K-Ar age determination of the volcanic rocks collected systematically from the Samburu Hills area where two types of fossil hominoids were discovered by the Japan-Kenya expedition, 1982 and discusses ages of the fossil hominoids discovered in the area. Tectonics and geochronology of the Gregory Rift system, northern Kenya will be described in detail elsewhere.

OUTLINE OF GEOLOGY AND PETROLOGY

The studied area is an eastern part of the Gregory Rift system, northern Kenya and is called the Samburu Hills area, 10 to 30 kilometres west of Baragoi (Fig. 1). The detailed geology of this area

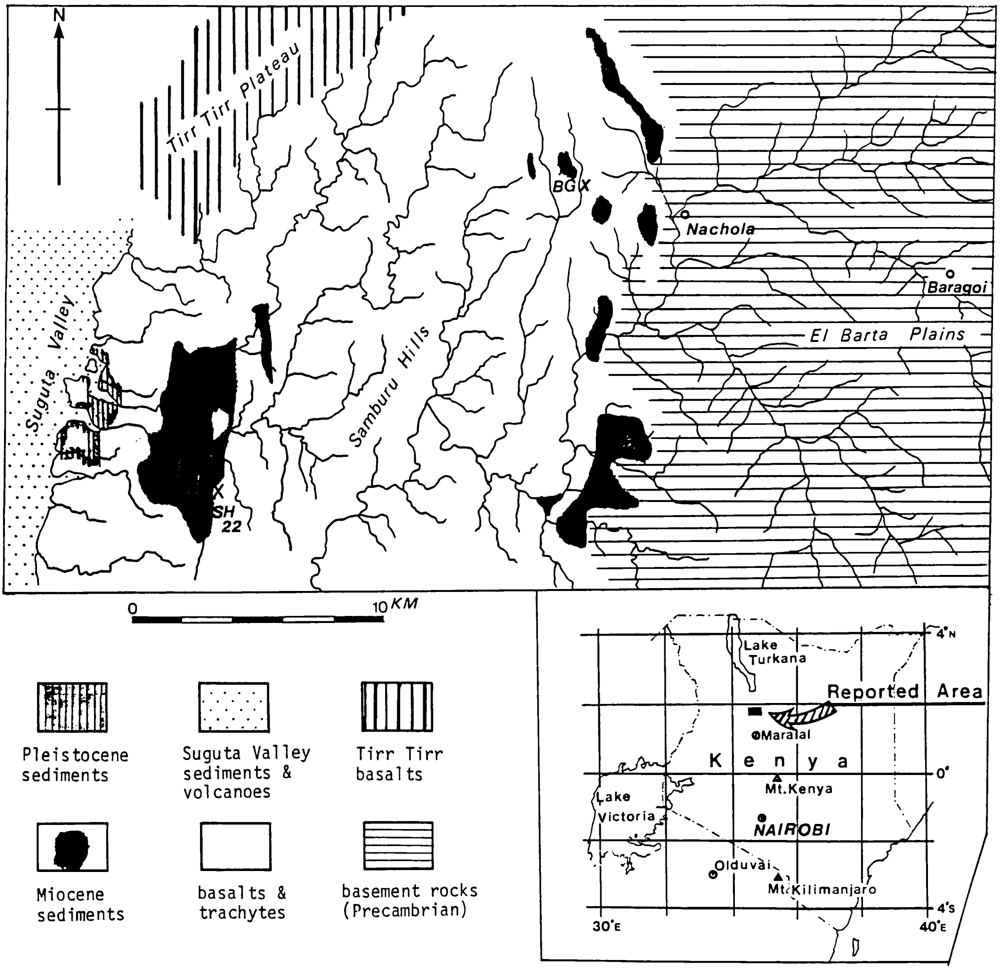

Fig. 1 Index map of the Samburu Hills area studied.

has been studied by Makinouchi *et al.,* (1984), Sawada *et al.,* (1986) and Tateishi (1986). The petrology of volcanic rocks in the area was investigated by Koyaguchi (1984). This area is underlain chiefly by the Miocene to Pleistocene volcanic rocks and clastic sediments which unconformably covers the latest Precambrian basement complex of the Mozanbique Belt. The Neogene system is divided into seven main formations, i.e., the Nachola, Aka Aiteputh, Namurungule, Nanyangaten, Kongia, Nagubarat and Tirr Tirr Formations (Fig. 2). In addition to them, there exist the Quaternary basalt lava flows and sediments. The constituents of each formation are summarized in Fig. 2.

The Nachola, Aka Aiteputh and Numurungule Formations had been deformed by faults and folds and generally tilted westwards, i.e., toward the rift floor. The Nanyangaten (basalt lava flows), Kongia (mainly basalt lava flows), Nagubarat (basalt lava flows) and Tirr Tirr (mainly basalt and rhyolite lava flows) Formations and the Quaternary basalts cover clinounconformably

	SUGUTA VALLEY	SAMBURU HILLS	BARAGOI RIVER	NACHOLA AREA
PLEISTO-CENE	basalts (0.12, 0.45) sediments	grey silts & fluviatile sediments	Alluvium (mud, sand & gravel)	Alluvium (mud, sand & gravel) basalts (1.75, 1.97)
PLIOCENE		TIRR TIRR F. alk. rhyolite tuff breccias sediments basalts (3.6, 3.8, 3.9)*		EMURU AKIRIM alkali trachytes basalts (4.11)
MIOCENE		NAGUBARAT F. basalts (5.34, 5.38)		
		KONGIA F. basalts (5.67, 6.03) sediments		
				NANYANGATEN F. basalts (7.29)
		NAMURUNGULE F. mud flow deposits, tuff, mud, sand & gravel		
		AKA AITEPUTH F. sediments basalts (10.8, 12.7, 14.5, 14.1, 14.2) trachytes (14.4, 14.9) pyroclastics basalts (14.5, 15.0)		AKA AITEPUTH F. basalts (11.8, 12.8) tuff sediments
			NACHOLA F. trachytes (15.0) pyroclastics (17.7) trachybasalts (18.2) basalts (17.7, 19.0, 19.2) sediments	NACHOLA F. trachytes (15.4) pyroclastics trachybasalts basalts sediments
PRECAM-BRIAN		PRECAMBRIAN BASEMENT COMPLEX		

Fig. 2 Stratigraphy of late Cenozoic in the Nachola area and Samburu Hills. Numbers show K-Ar ages (Ma) ; numbers marked * are after Baker et al. (1971) and others after this study. The stratigraphy is referred from Makinouchi et al. (1984) and Sawada et al. (1987).

the Mumurungule Formation and/or the underlying formations (Baker, 1963 ; Makinouchi *et al.,* 1984 ; Sawada *et al.,* 1987).

Koyaguchi (1984) divided the basaltic rocks in the area into three types, ankaramite observed in the Aka Aiteputh and Kongia Formations, olivine basalt in all the formations and hawaiite in the Aka Aiteputh, Kongia and Tirr Tirr Formations. He also divided the differentiated rocks in the area into four types, phonolitic trachyte in the Nachola Formation, sodalite trachyte in the Aka Aiteputh Formation, trachyte welded tuff in the Nachola and Aka Aiteputh Formations and alkali rhyolite in the Tirr Tirr Formation. The bulk chemistry of these volcanic rocks shows that most of them belong to alkaline rock suites on the basis of definition using silica—alkali diagram by Macdonald and Katsura (1964).

Sample preparation

Rock samples to be dated were collected systematically from the Nachola, Aka Aiteputh, Kongia, Nagubarat, Nanyangaten and Tirr Tirr Formations. Two samples from a scoria cone in the rift floor (Suguta valley) and two from a basalt lava flow covering Precambrian in a part about 5 kilometers east of the Nachola village were also collected. Their locations are shown in Fig. 3. They are almost from basalt lava flow and in part from the lava flows of the differentiated rocks (phonolitic trachytes, sodalite trachytes, trachyte welded tuff and alkali rhyolites).

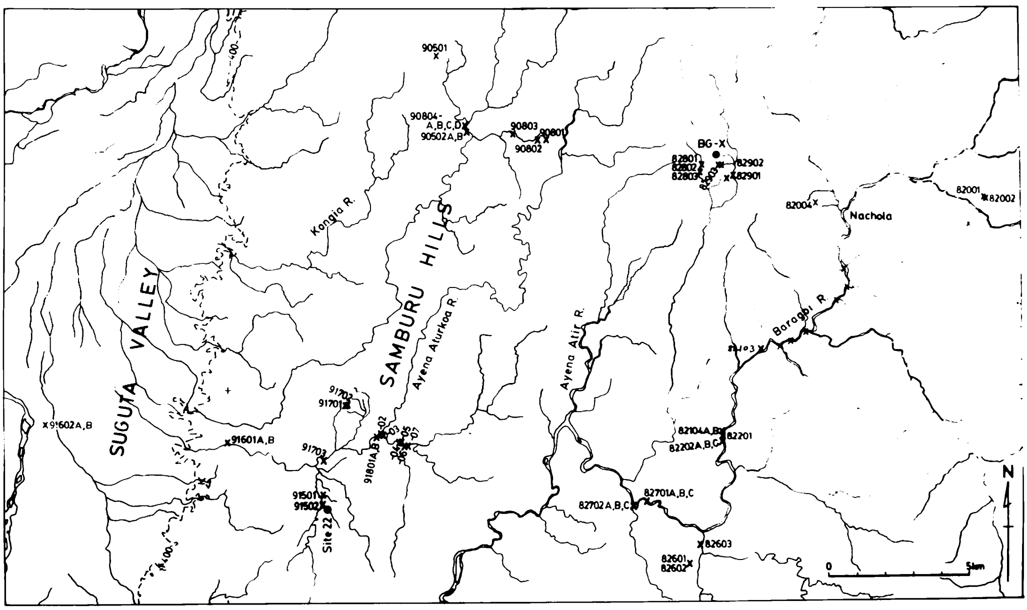

Fig. 3 Locality map of the studied specimens.

The rock samples were crushed and sieved, and the 80 to 100 mesh size fraction was used for the K-Ar age determinations. The sieved 80 to 100 mesh size fraction was washed by using distilled water to exclude powder residue from the fraction and then dried in a oven (100°C). The magnetic fraction such as oxide minerals and iron fragments contaminated in the crushing was excluded with an isodynamic separator. The fraction after these treatments (80 to 100 mesh size) was used for the argon analysis. A portion of the fraction was ground using an agate mortar, and the resulting sample powder was analyzed for potassium.

Analytical procedure of potassium and argon

As the details of analytical procedure of potassium and argon have been reported by Nagao *et al.* (1983), the procedure will be outlined here.

Potassium analysis was carried out by flame photometry using a 2000 ppm Cs buffer. The decomposition of powder sample for analysis by flame photometry was achieved with HF and HNO_3 treatment in a tefron beaker. Multiple runs of two chemical standards (JG-1 and JB-1) showed that the accuracy of this method was to within 3%. Argon was analyzed on a 30 cm radius sector type mass spectrometer with a single collector system by an isotopic dilution method using an argon 38 spike. Calibration of the argon 38 spike is accurate to within about 1% (Nagao *et al.*, 1984). The sample of 80 to 100 mesh size wrapped up with alumum foil was preheated for about 12 hours at about 150°C and then its argon was extracted at 1500°C on an ultrahigh vacuum line of which the atmospheric 40 argon blank was less than 5×10^{-9} ccSTP. The clean up of reactive gases was done by Ti-Zr scrubber. Mass discrimination was checked with atmospheric argon more than once a day.

Potassium and radiogenic argon 40 contents in samples analysed by the described method are for convenience expressed in terms of "wt.%" and "ccSTP/g (STP means the condition 0°C, 1 atm)" in this paper, respectively. If the potassium and the argon contents are equal to (K) wt.% and ($^{40}Ar^{rad}$) ccSTP/g and the decay constants (λ_e and λ_β) for ^{40}K to ^{40}Ar and ^{40}Ca, and ^{40}K content ($^{40}K/K$) in potassium are 0.581×10^{-10}, 4.962×10^{-10} and 0.0001167 by steiger and Jager (1977), respectively, the age is given by

$$t\ (\mathrm{Ma}) = 1.804\times10^{3}\ \ln\left(1+1.428\times10^{-4}\,\frac{[^{40}\mathrm{Ar}^{\mathrm{rad}}]\ 10^{-8}\ \mathrm{ccSTP/g}}{[\mathrm{K}]\ \mathrm{wt\%}}\right) \qquad (1)$$

The error of the K-Ar age determination depends on the precision of the analysis for potassium and argon in the sample. It also depends on the fraction of atomospheric argon in the sample because a correction to exclude atmospheric argon from the analysed total argon is necessary to calculate the age. This paper will use the following equation for the error of K-Ar age determination described by Nagao *et al.* (1984):

$$dt = \frac{1.804 \times 10^3 \times 1.428 \times 10^{-4}\ [^{40}Ar^{rad}]}{[K] + 1.428 \times 10^{-4}\ [^{40}Ar^{rad}]} \{(\frac{\Delta[^{40}Ar^{rad}]}{[^{40}Ar^{rad}]})^2 + (\frac{\Delta[K]}{[K]})^2\}^{1/2} \qquad (2)$$

where $\Delta(^{40}Ar^{rad})$ and $\Delta(K)$ are the error of the analysed radiogenic argon 40 and potassium, respectively. The approximate equation to calculate the error described by Cox and Dalrymple (1967) is not used here because their equation gives significantly smaller value in the calculation than the equation by Nagao *et al.* (1984). This tendency giving the smaller value gets more distinct in K-Ar age determination of young volcanic rocks.

K-Ar ages of volcanic rocks

K-Ar age data of the volcanic rocks collected from the Samburu Hills area are shown in Table 1. Potassium analysis was done more than twice for each specimen and the average value of two analyses of which the potassium contents were overlapped within the error range (3%) of each analysis was used to calculate the K-Ar ages. Argon was also analysed more than twice for each sample except for two specimen (84090804 A and 84091601 A). The error on each K-Ar age determination from the equation (2) takes no account of the heterogeneity of grained sample and the systematic error due ro timely or daily, or a longer period drift of this system. However, Table 1 shows good reproducibility of the K-Ar age determination in this paper because the difference of two ages is within the error for each K-Ar age determination. This suggests that it is possible to discuss the difference of ages of the analysed samples if the difference is significantly larger than the error on each K-Ar age determination.

It is important that rocks or minerals to be dated by the K-Ar method contain no radiogenic agron at the time of their formation. However, it has been revealed that this prerequisite is not always satisfied on each K-Ar age determination, i.e., a lot of radiogenic argon, called "excess argon" sometimes exists in rocks and minerals at the time of their formation. The excess radiogenic argon has been found and discussed in submarime basalts as well as subareal volcanic rocks by many investigators (cf. Ojima and Podoseck, 1983). Funkhouser *et al.* (1968) described that submarine basalts with a glass content greater than 80% gave much older ages than basalts with well crystallized groundmass in the same southern Pacific area and showed that the quenched glass retained the greatest amount of excess argon. The excess radiogenic argon has also been observed in olivine megacrysts of Kapuha lava, Hawaii by Kaneoka and Takaoka (1978). Recently, the author (T. I.) also observed the excess radiogenic argon in the volcanic glass of "AT" ash of Aira volcano, Japan. From these observations it could be suggested that the excess radiogenic argon existed originally in the magma and has been retained in part at the time of eruption because of insufficient degassing as a result of quick cooling of magma, or the presence of extremely coarse-grained crystals. Although a lot of excess argon are not common in subareal volcanic rocks, it is necessary to select carefully the volcanic rocks which are to be used for K-Ar age determination. Although no definite criteria for selection exists, it seems wise to remove extremely large phenocrysts and to avoid rapidly quenched volcanic rocks. If whole rock samples have to be used for

Table 1 K-Ar age data of 44 volcanic rocks collected systematically from the Samburu Hills area. The location of them is seen in Fig. 3. The supperscrip "NG" on sample number shows the specimen which is not good in discussing the eruption age (see text).

Number of Specimen	Numbers in Laboratory	Potassium (wt. %)	Rad. argon 40 (10^{-8} ccSTP/g)	K-Ar age (Ma)	Air conc. (%)
84082001	S 12- 24	1.17±0.04	8.7±1.1	1.91±0.24	78.6
	S 12- 25		7.2±1.1	1.58±0.26	83.1
84082002	S 12- 10	1.16±0.03	8.79±0.80	1.95±0.18	71.7
	S 12- 11		8.96±0.66	1.99±0.15	66.1
84082004	S 12- 21	0.70±0.02	19.4±1.4	7.14±0.54	64.9
	S 12- 22		20.2±1.4	7.43±0.56	64.8
84082103	S 12- 12	0.82±0.02	56.7±2.1	17.7±0.8	39.6
	S 12- 13		56.3±2.0	17.6±0.8	38.4
84082202A	S 13-204	0.77±0.02	58.6±1.0	19.6±0.6	32.0
	S 13-242		56.0±1.0	18.8±0.6	39.3
84082202B	S 12- 14	1.07±0.03	77.9±2.6	18.7±0.8	33.8
	S 12- 20		80.7±2.6	19.3±0.8	33.4
84082202C	S 12- 18	1.03±0.03	76.4±2.2	19.0±0.8	26.1
	S 12- 23		73.9±2.3	18.4±0.8	31.6
84082601^{NG}	S 12- 1	4.57±0.14	240.3±1.3	13.5±0.4	12.4
	S 12- 6		249.0±5.7	14.0±0.5	9.53
84082602	S 12- 8	3.05±0.09	206.0±6.6	17.3±0.8	32.6
	S 12- 9		214.8±7.0	18.1±0.8	33.1
84082603	S 12- 15	1.49±0.04	108.5±2.6	18.7±0.7	14.2
	S 12- 16		108.3±2.7	18.6±0.7	13.9
84082701A^{NG}	S 12- 43	4.46±0.13	209.6±4.3	12.1±0.4	3.77
	S 12- 44		216.8±4.5	12.5±0.4	3.35
84082701B^{NG}	S 12- 40	4.60±0.14	239.7±5.3	13.4±0.5	10.4
	S 12- 45		240.1±1.3	13.4±0.4	9.68
84082701C	S 12- 52	4.28±0.13	246.2±1.4	14.8±0.5	9.72
	S 12- 53		251.5±1.5	15.1±0.5	8.98
84082702A^{NG}	S 12- 50	4.79±0.14	231.8±1.4	12.4±0.4	7.59
	S 12- 51		219.8±1.2	11.8±0.4	6.89
	S 12-102		260.3±5.7	14.0±0.5	7.77

—to be continued—

Table 1

Number of Specimen	Numbers in Laboratory	Potassium (wt. %)	Rad. argon 40 (10^{-8} ccSTP/g)	K-Ar age (Ma)	Air conc. (%)
84082702B[NG]	S 12- 58	4.70±0.14	258.3±1.3	14.1±0.4	6.47
	S 12- 59		257.8±1.3	14.1±0.4	6.74
84082702C[NG]	S 12- 41	4.97±0.15	270.7±5.8	14.0±0.5	7.01
	S 12- 42		273.2±5.9	14.1±0.5	7.01
84082801[NG]	S 12- 35	2.75±0.08	169.3±7.4	15.8±0.8	48.9
	S 12- 36		170.5±7.9	15.9±0.9	50.8
84082802	S 12- 31	0.69±0.02	31.3±1.6	11.6±0.7	55.5
	S 12- 32		31.9±1.6	11.9±0.7	54.8
84082901	S 12- 33	3.88±0.12	225.2±4.9	14.9±0.6	7.46
	S 12- 34		241.1±5.5	15.9±0.6	12.6
84082903	S 13-205	0.76±0.02	38.3±1.5	13.0±0.6	66.4
	S 13-243		37.1±1.3	12.6±0.5	65.3
84090104	S 12- 48	0.51±0.02	8.32±0.26	4.20±0.21	80.1
	S 12- 49		7.95±0.30	4.01±0.22	80.2
84090801	S 12- 37	0.58±0.02	29.5±1.0	13.0±0.6	34.2
	S 12- 38		30.4±1.0	13.5±0.6	33.6
84090802	S 12- 29	1.21±0.04	68.6±1.8	14.5±0.6	23.2
	S 12- 30		69.5±1.8	14.7±0.6	21.9
84090803	S 12- 76	0.96±0.03	54.2±1.6	14.5±0.6	29.5
	S 12- 77		54.4±1.6	14.5±0.6	29.2
84090804A	S 12- 54	0.42±0.01	22.30±0.28	13.6±0.4	46.7
84090804B	S 12- 63	0.82±0.02	44.7±1.2	14.0±0.5	23.1
	S 12-101		45.8±1.3	14.3±0.5	24.8
84090804C	S 12- 60	1.24±0.04	73.0±1.9	15.1±0.6	20.0
	S 12- 61		72.1±1.8	14.9±0.6	19.9
84090804D	S 12- 56	0.93±0.03	52.62±0.41	14.5±0.5	29.5
	S 12- 57		54.30±0.40	15.0±0.5	29.2
84091501	S 12- 82	0.94±0.03	39.2±1.7	10.7±0.6	47.8
	S 12- 83		39.4±1.7	10.8±0.6	47.1

—to be continued—

Table 1

Number of Specimen	Numbers in Laboratory	Potassium (wt.%)	Rad. argon 40 (10^{-8} ccSTP/g)	K-Ar age (Ma)	Air conc. (%)
84091502	S 12-64	0.46±0.01	22.4±1.1	12.5±0.7	54.5
	S 12-65		23.2±1.2	12.9±0.7	55.6
84091601A	S 12-80	2.13±0.06	47.0±1.6	5.67±0.25	37.9
84091601B	S 12-74	0.76±0.02	17.9±1.0	6.06±0.36	56.2
	S 12-75		17.7±1.0	5.99±0.38	58.5
84091602A	S 12-91	0.78±0.02	0.29±0.14	0.10±0.05	98.6
	S 12-92		0.40±0.18	0.13±0.06	98.3
84091602B	S 12-93	0.83±0.02	1.11±0.68	0.34±0.21	98.7
	S 12-94		1.76±0.67	0.55±0.21	98.0
84091701	S 12-89	1.10±0.03	23.0±1.8	5.39±0.43	67.7
	S 12-90		22.5±1.8	5.29±0.44	68.4
84091702	S 12-87	1.20±0.04	26.06±0.93	5.59±0.27	39.1
	S 12-88		24.09±0.84	5.16±0.25	37.5
84091703	S 12-78	0.76±0.02	42.8±1.7	14.5±0.7	43.5
	S 12-79		42.6±1.7	14.4±0.7	44.2
84091801A	S 12-97	1.05±0.03	58.33±0.41	14.3±0.4	25.3
	S 12-98		53.76±0.34	13.1±0.4	25.8
84091801B	S 12-72	1.15±0.03	63.0±2.0	14.1±0.6	33.4
	S 12-73		63.0±2.0	14.1±0.6	33.3
84091802	S 12-85	3.93±0.12	152.1±4.3	9.94±0.41	26.8
	S 12-86		155.9±4.4	10.19±0.42	26.2
84091803	S 12-95	3.93±0.12	225.2±1.2	14.7±0.5	7.45
	S 12-96		215.6±1.0	14.1±0.4	7.72
84091804	S 12-70	4.07±0.12	244.6±5.6	15.4±0.6	12.9
	S 12-71		228.5±5.3	14.4±0.5	13.2
84091805	S 12-66	1.32±0.04	74.7±2.1	14.5±0.6	25.6
	S 12-67		74.5±2.0	14.5±0.6	24.4
84091807	S 12-68	1.40±0.04	82.2±2.2	15.1±0.6	24.0
	S 12-69		80.6±2.2	14.8±0.6	24.2

the age determination, it is quite important to examine carefully the K-Ar ages of many types of volcanic rocks from the same outcrop, for example, porphyritic and aphyric ones before the discussion for their eruption ages.

This paper checked some volcanic rocks in the present area for their excess radiogenic argon. The sample Nos. 84090804 A, B, C and D are olivine basalts collected from a big outcrop of the Aka Aiteputh formation. Their sampling location from the outcrop are shown in Fig. 4 PO which shows the stratigraphical ascending order of their samples D (lower), C, B and A (higher). Nos. A, B and D are porphyritic, and No. C is aphyric (Figs. 4 A, 4 B, 4 D and 4 C). Their K-Ar age data in Table 1 suggest that no significant difference between the ages of porphyritic and aphyric rocks is observed and rather seems to show that their ages get younger in the ascending order of stratigraphy. The sample Nos. 84082202 A, B and C are porphyritic olivine basalt with or without vesicles (Figs. 5 A, 5 B) and trachybasalt collected from an outcrop of the Nachola formations, respectively. The ages of these three types of rocks are the same within the error of each K-Ar age determination. The similar result is obtained from some basalts of other outcrops ; Nos. 84091801 A and B with or without vesicles from the Aka Aiteputh formation and Nos. 84091601 A (aphyric) and B (porphyritic) from the Kongia formation (Figs. 6 A and 6 B) (Tables 1 and 2). These facts suggest that coarse-grained phenocrysts in the basalt lava flows in the present area had no significant amount of excess radiogenic argon, and that the existence of vecicle in rocks had no influence on the K-Ar age determination. Sample Nos. 84091602 A and B collected from the scoria cone in the rift floor are the rocks occuring sporadically on top of the cone, and are not used for the discussion mentioned above.

Sample No. 84082801 is a tuff with brownish color collected from lower part of the Aka Aiteputh formation and its age is 15.8 ± 0.8 Ma significantly older than a basalt lava flow (84082903, 13.0 ± 0.6 and 12.6 ± 0.6 Ma) of the stratigraphically lower part and rather similar to the phonolitic trachyte (84082901, 14.9 ± 0.6 and 15.9 ± 1.6 Ma) of the Nachola formation in age. The tuff is glassy and often contain lithic fragment of phonolitic trachyte (Fig. 6 C) and fragment of quartz probably derived from the Precambrian rocks (Fig. 6 D). This fact suggests that the K-Ar age does not show the eruption age because of possibility of existing of excess radiogenic argon from the magma and fragments. Sample Nos. 84082701 A, B and C, and 84082702 A, B and C are phonolitic trachytes collected from the Nachola formation. Their are from aphyric part of the phonolitic trachyte just above wellded tuff in the formation, and with green or dark blue color due to chlorite like minerals formed in the alteration (Figs. 7 A, 7 B, 7 C and 7 D). Their K-Ar ages are significantly younger than the ages of fresh porphyritic phonolitic trachyte (Figs. 7 E and 7 F) with black color (No. 84082701 C, 14.8 ± 0.5, 15.1 ± 0.5 Ma) having similar age to the fresh aphyric phonolitic trachyte (84082901, 14.9 ± 0.6, 15.9 ± 0.6 Ma) collected from the different outcrop. No. 84082701 A with the most greenish color have the youngest age (12.6 Ma). This shows that such type of alteration rejuvenated the K-Ar age of rocks to 12.6 from 15.0 Ma, and suggests that the little bit of alteration (Nos. 84082701 B and 84082702 B) was also responsible for the rejuvenation of about one million years in these types of rocks.

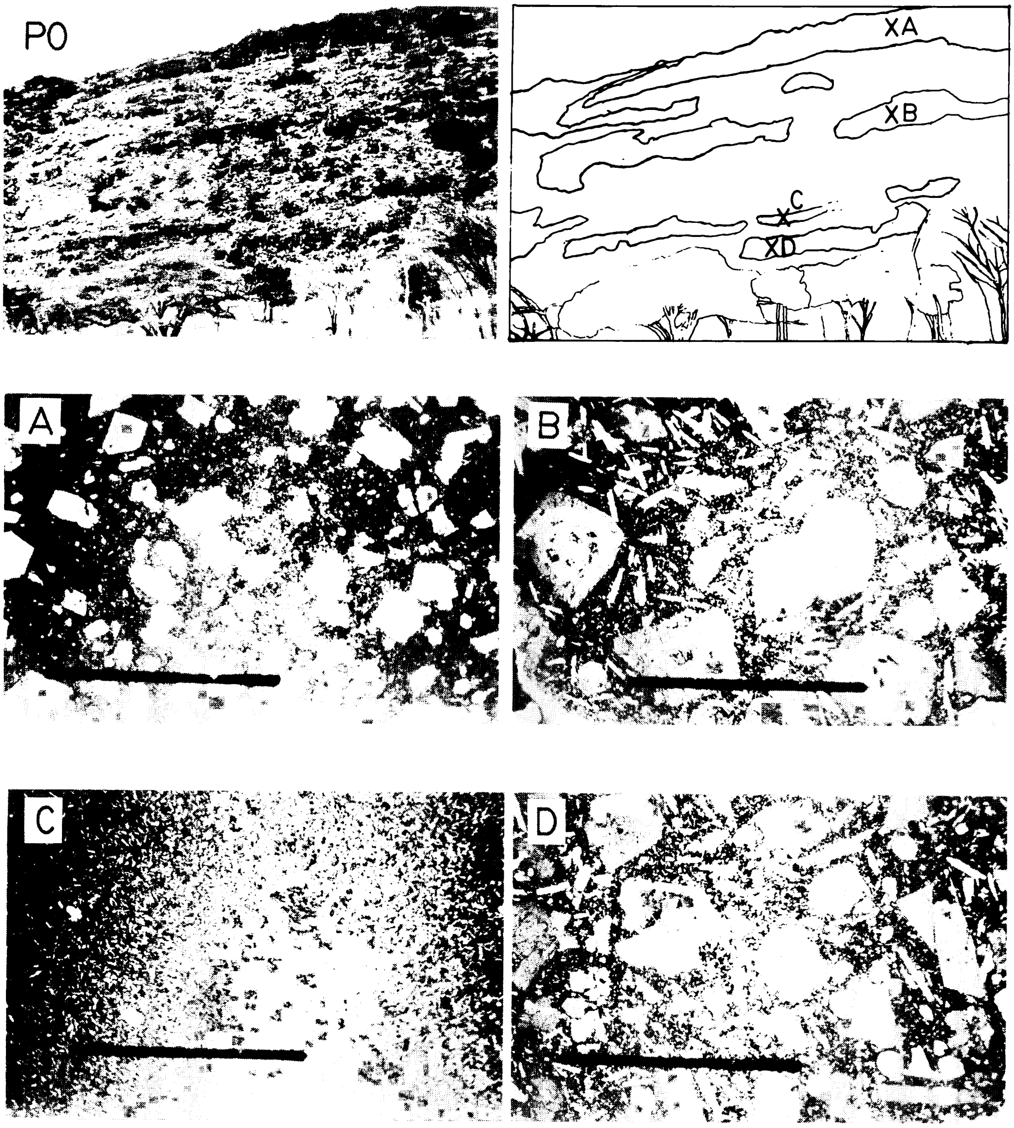

Fig. 4 PO: photograph of an outcrop in Aka Aiteputh formation from which three porphyritic basalts and an aphyric basalt were collected. A, B, C and D: photographs of thin sections of the four basalts, 84090804 A (porphyritic), 84090804 B (porphyritic), 84090804 C (aphyric) and 84090804 D (porphyritic), respectively.

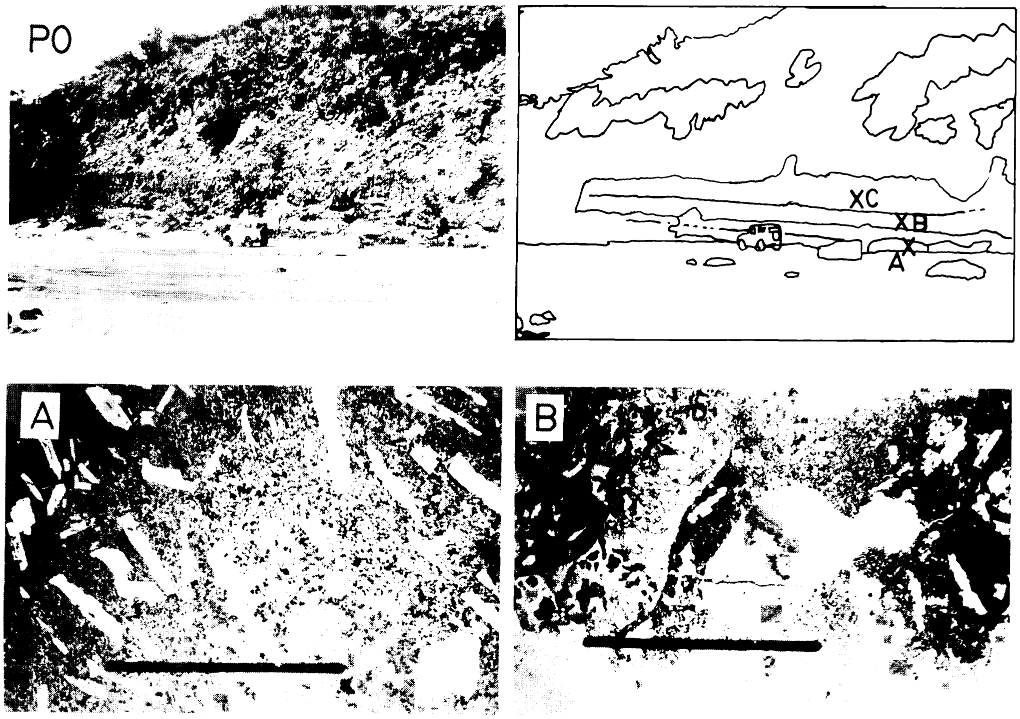

Fig. 5 PO: photograph of an outcrop in Nachola Formation from which two olivine basalts with or wihthout vesicles and a trachyte were collected. A and B: photographs of thin sections of the two basalts, 84082202 A and 84082202 B (with vesicles), respectively.

AGE OF FOSSIL HOMINOIDS

As mentioned before, the K-Ar ages of volcanic rocks in the present area do not always show the eruption ages of rocks. However, it is possible to use the K-Ar ages as the eruption ages if the tuff containing the excess radiogenetic argon and the extremely altered rocks are excluded, and only the fresh lava flows are dated as discussed above. The superscript "NG" on sample number in Table 1 shows the specimen which is not good in discussing the eruption age. The K-Ar ages of specimen without "NG" are shown on the columner sections by Sawada *et al.* (1987) as shown in Fig. 8 which indicates the good correlation between the stratigraphy confirmed by the geological survey and the K-Ar ages of volcanic rocks collected from the area.

The two types of fossil hominoids have been discovered in the sedimentary rocks of the area, and one of them was in the Namurungule Formation of the Samburu Hills and another one in middle part of the Aka Aiteputh Formation in the Nachola area. Unfortunately, it is impossible to date these sediments yielding the fossil hominoids with the K-Ar age determination method. However, the detailed K-Ar age determination of the volcanic rocks occuring around the sediments could make it easy to estimate the possible range of ages of the fossil hominoids. Fig. 8 suggests that the

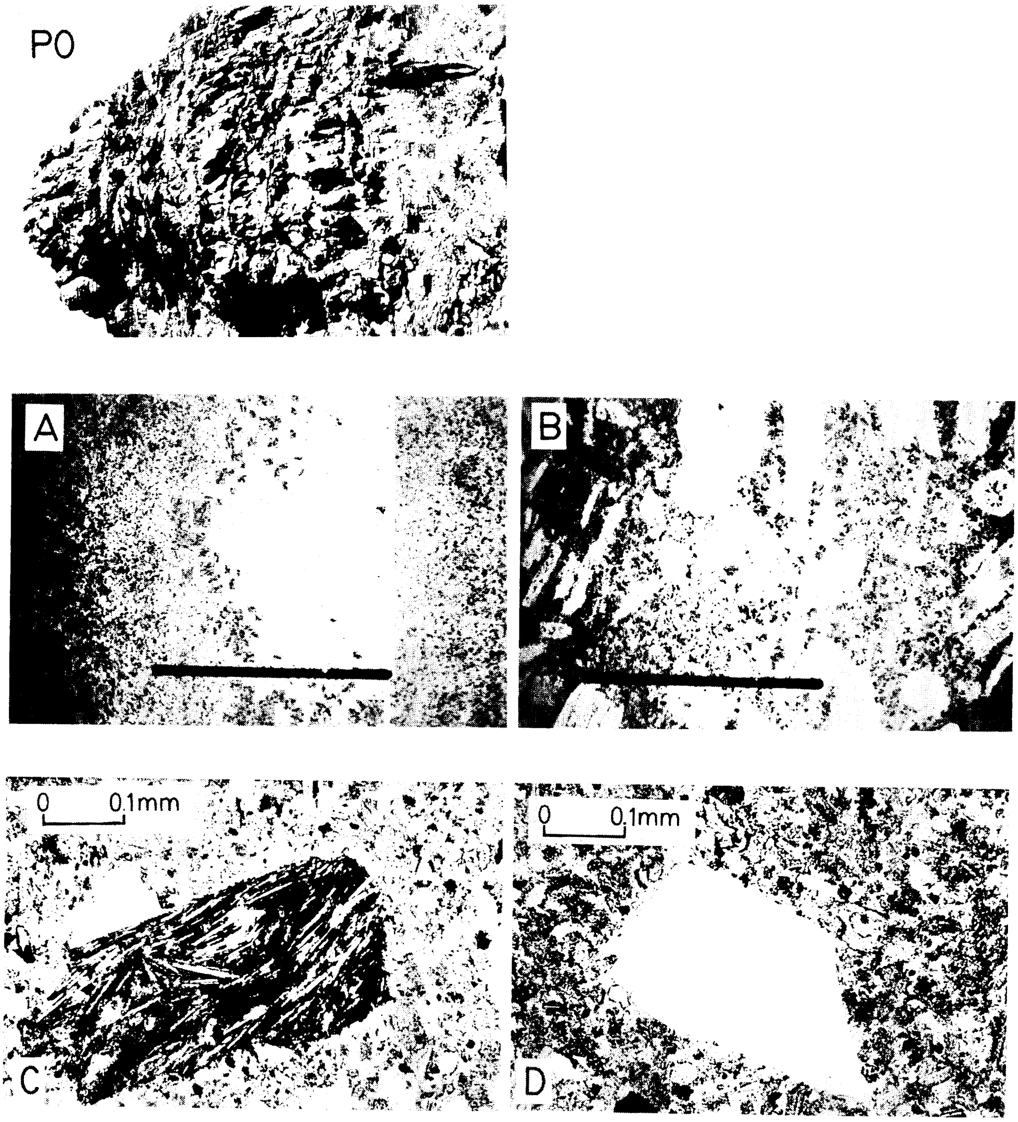

Fig. 6 PO: photograph of an outcrop in Kongia formation from which two basalts were collected. A and B: photographs of thin sections of the two basalts, 84091601 A (aphyric) and 84091601 B (porphyritic), respectively. C: microphotograph of lithic fragment of trachyte in tuff, open nicol (84082801). D: microphotograph of quartz fragment in tuff, open nicol (84082801).

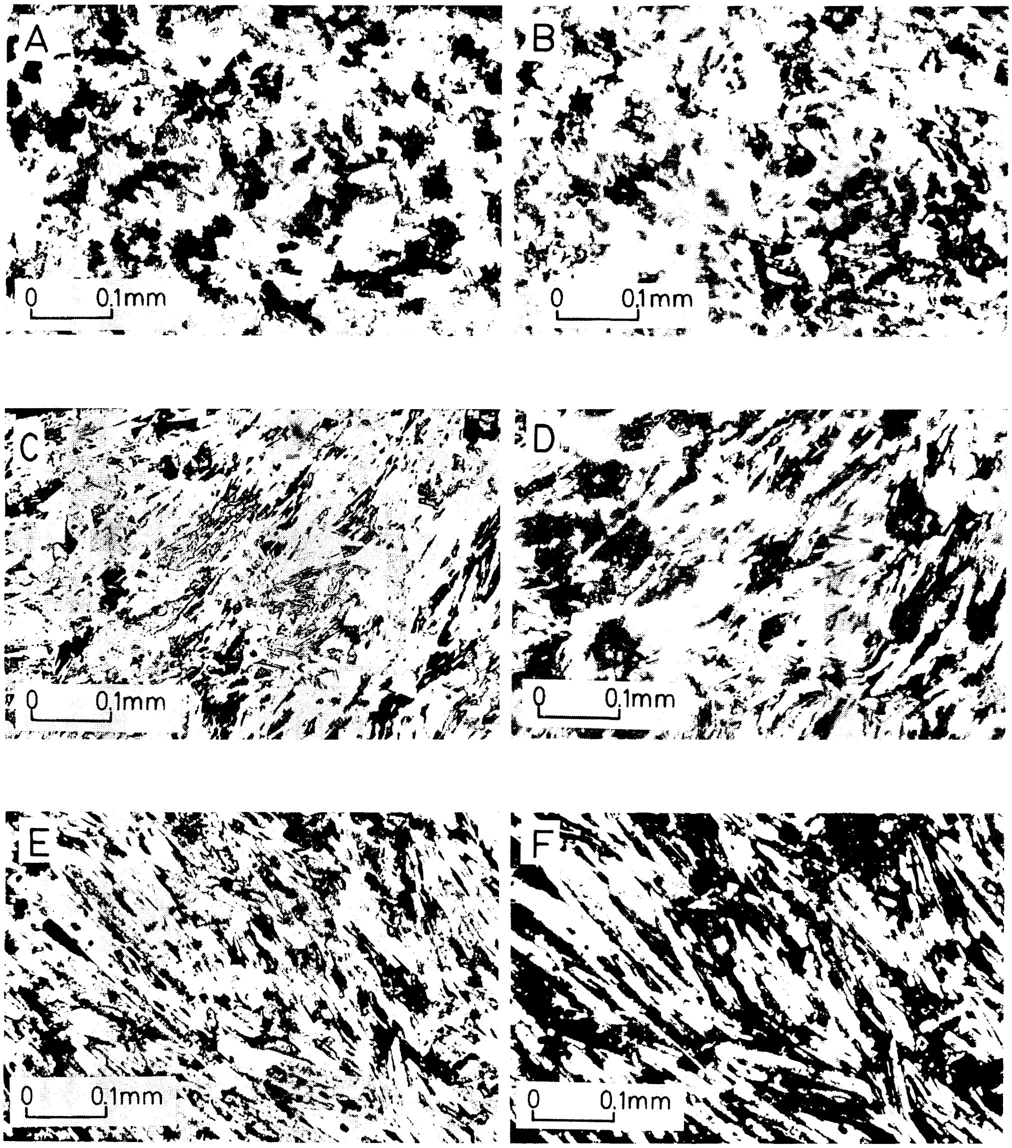

Fig. 7 Microphotographs of groundmass texture of phonolitic trachytes collected from an outcrop in the Nachola Formation. A and B: much altered aphyric rock (84082701 A), open and cross nicols, respectively. C and D: little bit altered aphyric rock (84082701 B), open and cross nicols, respectively. E and F: fresh porphyritic rock (84082701 C), open and cross nicols, respectively.

Table 2 Rock name and occurrence, and formation name of the dated volcanic rocks from the Samburu Hills area.

Sample No.	Rock name and occurrence	Formation
84082001	olivine basalt of Baker (1963)	
84082002	olivine basalt of Baker (1963)	
84082004	olivine basalt of Baker (1963)	Nanyangaten
84082103	porphyritic olivine basalt,	Nachola
84082202A	basalt	Nachola
84082202B	basalt with vesicle filled with minerals	Nachola
84082202C	trachybasalt	Nachola
84082601^{NG}	aphyric trachyte, altered	Nachola
84082602	welded tuff	Nachola
84082603	basalt	Nachola
84082701A^{NG}	aphyric trachyte, altered	Nachola
84082701B^{NG}	aphyric trachyte, altered in part	Nachola
84082701C	phonolitic trachyte	Nachola
84082702A^{NG}	aphyric trachyte, altered	Nachola
84082702B^{NG}	aphyric trachyte, altered in part	Nachola
84082702C^{NG}	aphyric trachyte, altered in part	Nachola
84082801^{NG}	tuff containing xenoliths and xenocrysts	Aka Aiteputh
84082802	aphyric basalt	Aka Aiteputh
84082901	aphyric trachyte	Nachola
84082903	basalt	Aka Aiteputh
84090104	alkali trachyte of Baker (1963)	Muruakirim
84090801	porphyritic olivine basalt	Aka Aiteputh
84090802	aphyric basalt	Aka Aiteputh
84090803	aphyric basalt	Aka Aiteputh

—to be continued—

Table 2

Sample No.	Rock name and occurrence	Formation
84090804A	porphyritic basalt	Aka Aiteputh
84090804B	porphyritic basalt	Aka Aiteputh
84090804C	aphyric basalt	Aka Aiteputh
84090804D	porphyritic basalt	Aka Aiteputh
84091501	Basalt with vesicle filled with minerals	Aka Aiteputh
84091502	porphyritic basalt	Aka Aiteputh
84091601 A	aphyric basalt	Kongia
84091601 B	porphyritic basalt	Kongia
84091602 A	basalt with vesicle	scoria cone
84091602 B	basalt	scoria cone
84091701	basalt	Nagubarat
84091702	basalt	Nagubarat
84091703	basalt	Aka Aiteputh
84091801 A	basalt with vesicle	Aka Aiteputh
84091801 B	basalt	Aka Aiteputh
84091802	sodalite trachyte with fine cleavage	Aka Aiteputh
84091803	sodalite trachyte	Aka Aiteputh
84091804	sodalite trachyte	Aka Aiteputh
84091805	basalt	Aka Aiteputh
84091807	basalt	

Kenyapithecus discovered at the Site BG-X in the middle part of the Aka Aiteputh Formation is 14.9 ± 0.6 to 12.6 ± 0.5 Ma in age and the Samburu hominoids discovered at the Site SH-22 in the Namurungule Formation, 10.7 ± 0.6 to 5.7 ± 0.3 Ma. As mentioned before, the Kongia, Nagubarat and Tirr Tirr Formations clinounconformably cover the Namurungule and underlying formations. The Nanyangaten Formation occuring in the Nachola area also clinounconformably overlies the Aka Aiteputh Formation (Sawada *et al.,* 1987). These points indicate that the structural gap exists between the Namurungule and Nanyangaten Formations. Therefore it is concluded that the Samburu hominoid fossil occurs in age between 10.7 ± 0.6 and 7.1 ± 0.5 Ma.

	SUGUTA VALLEY	SAMBURU HILLS	NACHOLA AREA
PLEISTO-CENE	basalts (0.12, 0.45) sediments	grey silts & fluviatile sediments	mud, sand & gravel basalts (1.8, 2.0)
PLIOCENE		Tirr Tirr F. alk. rhyolite tuff breccias sediments basalts (3.6 - 3.9)*	Emuru Akirim trachytes basalts(4.1)
UPPER MIOCENE		Nagbarat F. basalts (5.3, 5.4) Kongia F. basalts (5.7, 6.0) sediments	Nanyangaten F. basalts(7.3)

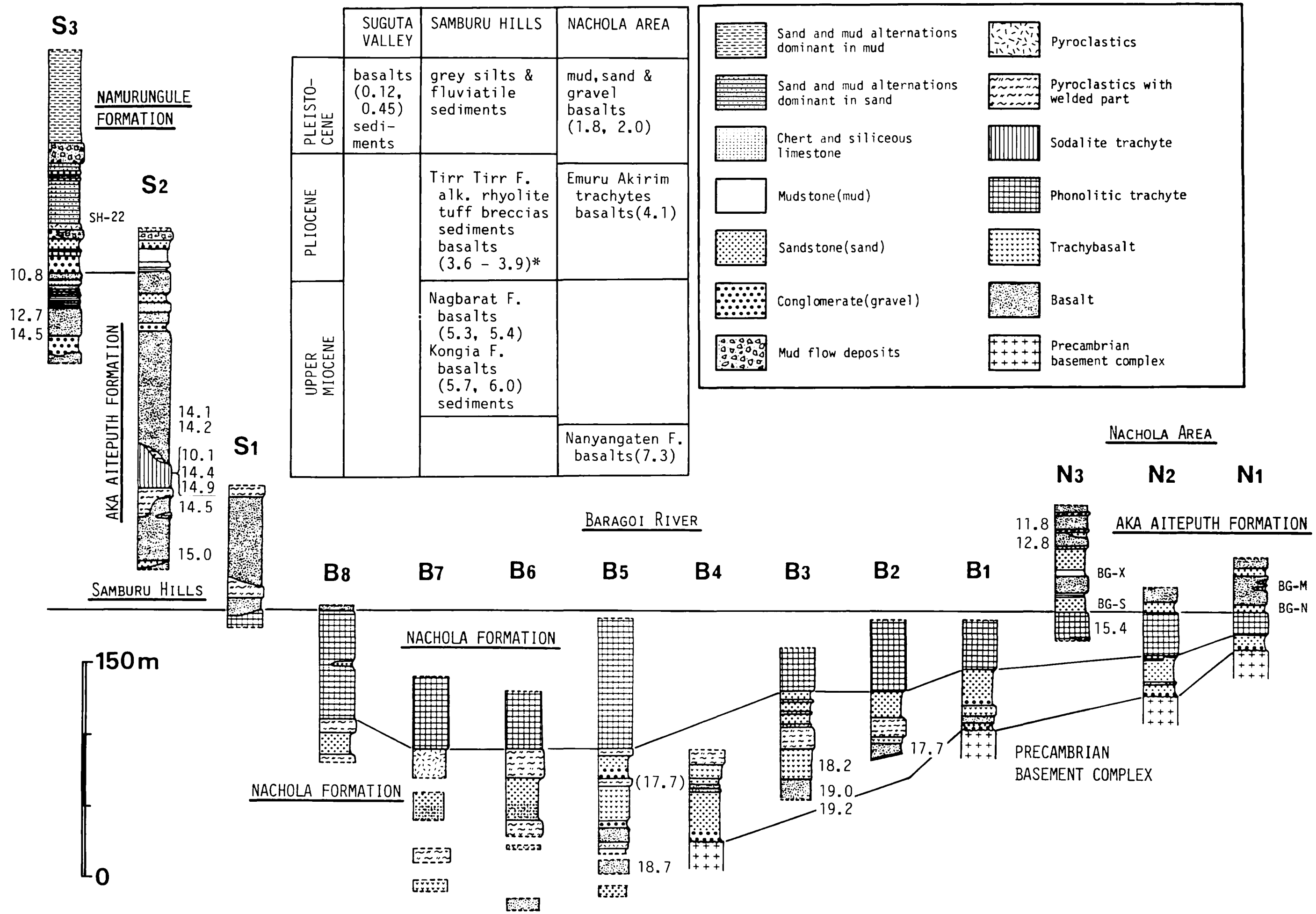

Fig. 8 Columner sections and K-Ar age of the Nachola, Aka Aiteputh and Namurungule Formations. Columner sections are referred from Sawada *et al.* (1987). Numbers show K-Ar ages (Ma). ( ): pyroclastics or volcanic sand.

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